REGIONAL PATTERN OF CLIMATES IN EUROPE ACCORDING TO THE THORNTHWAITE CLASSIFICATION*

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INTRODUCTION

Over ten years have elapsed since Thornthwaite (1948) published his revised classification of climates. Since that date, when the arrangement of climatic types in the United States was first published, a wide variety of studies have appeared concerning other areas: Canada (Sanderson, 1948), Turkey (Erinc, 1950), New Zealand (Garnier, 1951), Argentina (Burgos and Vidal, 1951), Rhodesias and Nyasaland (Howe, 1953), China (Chang, 1955), and others. More recently an evaluation of the revised classification of climates appeared in the *Annals* of the Association of American Geographers (Chang, 1959).

Chang notes the need for the development of a better energy budget formula to take into account the more significant role of radiation than air temperature in promoting evapotranspiration. Until the physicist or the meteorologist achieves this goal the geographer can continue to exploit the positive values of the classification: a better understanding of the macrovariations in climate over the earth's surface; the establishing of correlations or interrelationships between climatic elements (e.g., Thornthwaite's Moisture Index and the specialized procedure for calculating soil moisture) and other elements of the physical environment as a basis for understanding economic patterns of land use. This study examines the application of the 1948 Thornthwaite classification of climates to Europe, including the western part of the Soviet Union, and proceeds to compare the arrangement of climates on that continent with the pattern observed in the United States.

OBSERVATIONAL DATA

Blue Hill Meteorological Observatory in Milton, Massachusetts, recently completed a systematic revision of the time-honored volume of climatic data, Clayton's *World Weather Records*, and has made available a reasonably complete and hitherto unused series of climatic data for the European landmass. From this new wealth of world climatic data gathered at Blue Hill, 170 European stations were selected to provide the base for a series of climatic maps employing the 1948 Thornthwaite classification of climate (Fig. 1, Location of Stations).

AVERAGE ANNUAL THERMAL EFFICIENCY

Average annual thermal efficiency or potential evapotranspiration is essentially an expression of day length as well as temperature. Thornthwaite notes "(It) is not merely a growth index but expresses growth in terms of the water that is needed for growth. Given in the same units as precipitation it relates thermal efficiency to precipitation effectiveness."

Figure 2 reveals close spacing of isarithms of annual potential evapotranspiration (or water need as it is more simply expressed) in southern Europe, reflecting the marked climatic transition within the Mesothermals between the bulk of the northern European plain and the Mediterranean border land. Of the three Mesothermal climates represented, B_1^1 with a water need from 22.44 in. to 28.05 in. is most common. In the United States a comparable or even greater gradient is

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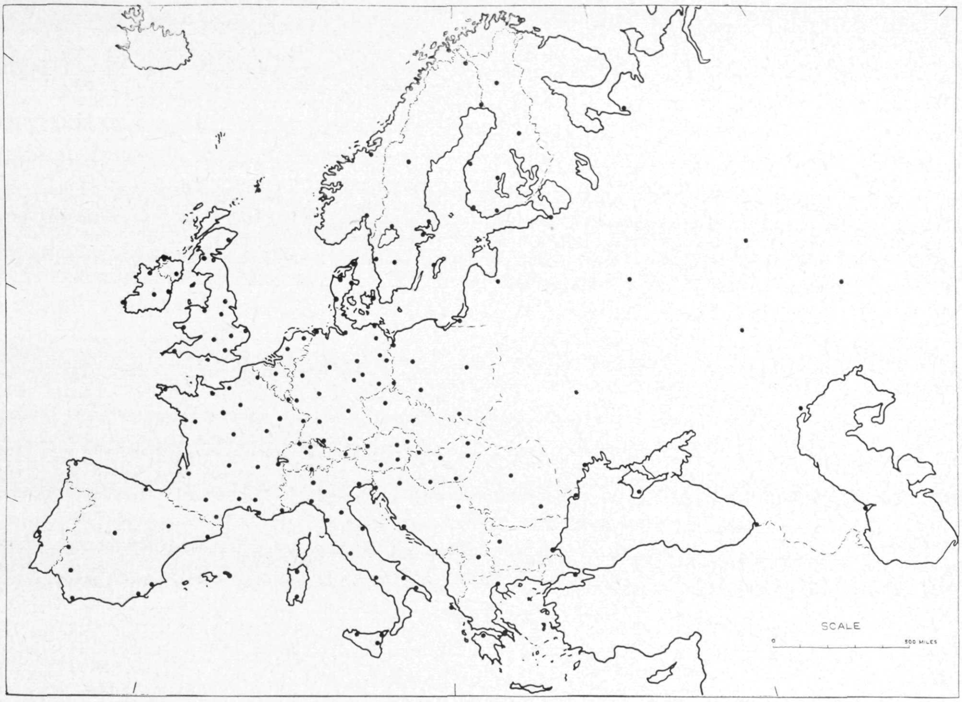


FIGURE 1. Location of stations.

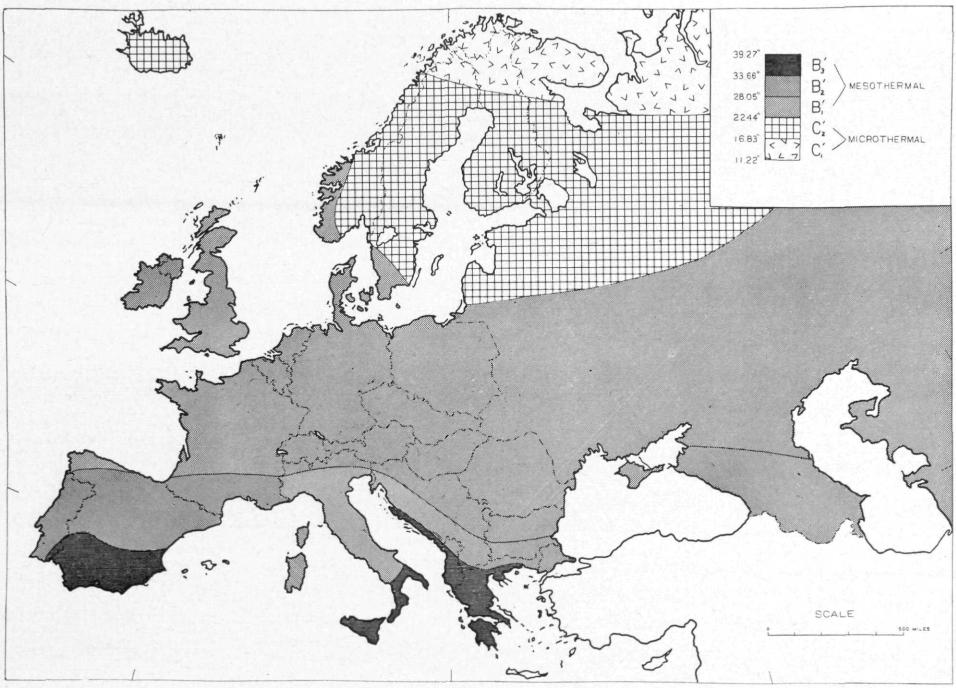


FIGURE 2. Average annual thermal efficiency.

found from Nebraska to southern Texas as well as from southeastern Pennsylvania to central Florida. B^1_1 is also the most extensive thermal efficiency type covering between ¼ and ⅓ of the country.

The thermal efficiency type C^1_1 (Microthermal), which covers much of northern Scandinavia and northernmost Soviet Union, is completely lacking in lowland sections of the United States. However, two thermal efficiency types at the opposite end of the scale, B^1_4 (Mesothermal: water need from 39.27 in. to 44.80 in.) and A^1 (Megathermal: water need in excess of 44.88 in.), occupy large sections of southeastern and southwestern United States, but are absent in Europe.

SUMMER CONCENTRATION OF THERMAL EFFICIENCY

Summer concentration of thermal efficiency (fig. 3) is the ratio of the potential

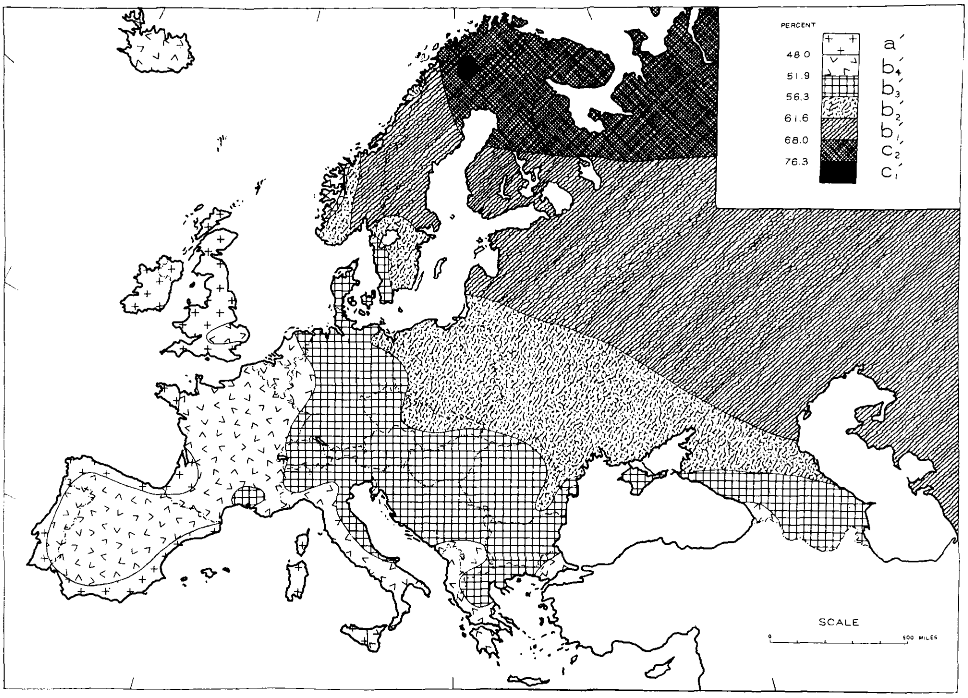


FIGURE 3. Summer concentration of thermal efficiency.

evapotranspiration of the three warmest months of the year to that of the annual total expressed as a percentage.

In some equatorial areas, where length of day and temperature values achieve a high degree of uniformity, the potential evapotranspiration of any three consecutive months will be 25 percent of the annual total. Near the poles, where the growing season is limited to a very small part of the year, the potential evapotranspiration of the three warmest months will be 100 percent of the annual total. Therefore, an "ideal" *latitudinal* pattern should exist if there were no complicating factors; where isarithms are not latitudinal in pattern Thornthwaite notes a condition of "abnormality."

The generally longitudinal orientation of isarithms in western Europe reflects the modification produced by onshore winds which raise winter temperatures, and, consequently, reduce the high concentration of thermal efficiency during the three summer months. A more nearly latitudinal pattern is found in eastern Europe away from the marine modification. In the United States, as might be expected, the bulk of the country east of the Rocky Mountains has a very nearly latitudinal pattern; west of the Cascade-Sierra Nevada Ranges the pattern is distinctly longitudinal. Application of Thornthwaite's system merely underlines the profoundly greater extent of winter marine influence in Europe than in the United States.

Iceland, the British Isles, Spain, and Portugal, Belgium, Luxembourg, and nearly all of France, Netherlands, Italy, Albania, and Greece have less than 52 percent of the thermal efficiency during the three warmest months of the year. The United States Pacific Coastal area and southeastern United States from south central Texas to the Virginia-North Carolina border are included in the same

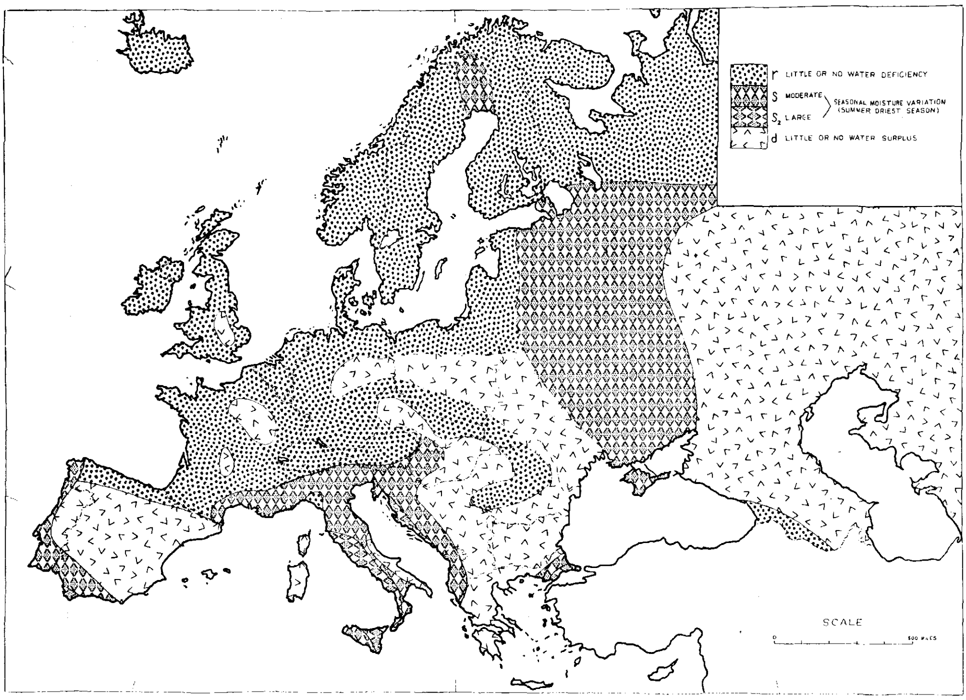


FIGURE 4. Seasonal variation of effective moisture.

groupings. The only major region appearing in Europe but lacking in lowland United States is found in northern Scandanavia and the northern Soviet Union where more than 68 percent of the thermal efficiency is concentrated during the three warmest months of the year. A small area in northernmost Sweden has more than three-fourths of its thermal efficiency during this period.

SEASONAL VARIATION OF EFFECTIVE MOISTURE

The measurement of the seasonal variation of effective moisture allows distinction between those climates *with* seasonal variation from those *without*. Further, with respect to the climates *with* seasonal variation, degrees of periods of dryness in moist climates and *degrees* of periods of moistness in dry climates are obvious.

Figure 4 shows that in much of northern and northwestern Europe little or no water deficiency occurs during any part of the year; large parts of western Soviet Union as well as southeastern, eastern, and southwestern Europe have little or no water surplus during the year. The region of little or no water surplus extends deeply into central Europe from the Black Sea with outliers in France and England.

Thornthwaite's definition of moderate seasonal moisture variation is one which will change the climate one-half grade; a large seasonal moisture variation is one which is sufficient to make the climate one grade dryer or moister than it would be otherwise. In Europe three distinct areas stand out with moderate seasonal moisture variations: the Swedish-Finnish borderlands; western Soviet Union from Leningrad to the Crimea; and sections of the Mediterranean borderlands.

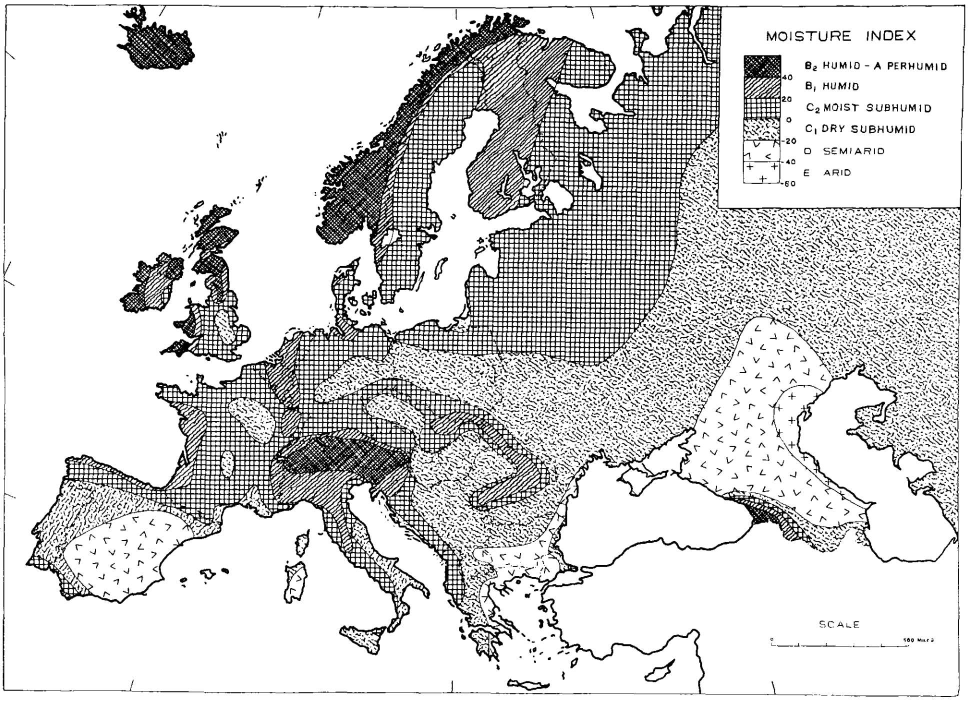


FIGURE 5. Moisture regions.

Regimes of potential evapotranspiration and precipitation and resulting effect of these variables upon water surplus, water deficiency, soil moisture utilization, and soil moisture recharge.

Large seasonal moisture variations are limited to southermost Spain, coastal southern Italy, adjacent Sicily, and European Turkey.

The absence of winter dry types in Europe lends support to Thornthwaite's observation that "These types are much less widely distributed over the earth than would be deduced from a study of the seasonal march of precipitation."

The United States on the other hand has, with the exception of the West Coast states, a far simpler distribution of regional types. Almost all of the United States east of the High Plains has little or no water deficiency. Almost all of the United States west of 100th meridian has little or no water surplus. Large scattered areas in eastern Texas and adjoining states as well as the lower Mississippi Valley and central Alabama have a moderate seasonal moisture variation.

MOISTURE REGIONS

Only slightly more than one-half of Europe lies within the limits of Thornthwaite's moist climates. Koeppen, on the other hand, restricted the dry climates to Spain and the Soviet Union, classifying fully four-fifths of the continent as humid. Figure 5 shows the zero moisture index value separating dry from humid climates penetrating westward from the Soviet Union into central Europe in two great arms: one extends through southern Poland and moves westward into Germany almost reaching the middle Rhine valley; the other extends up the

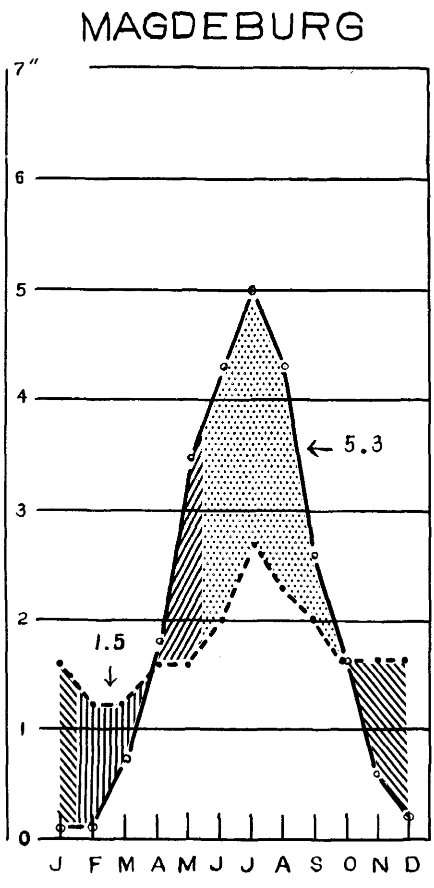


FIGURE 6. Magdeburg, East Germany

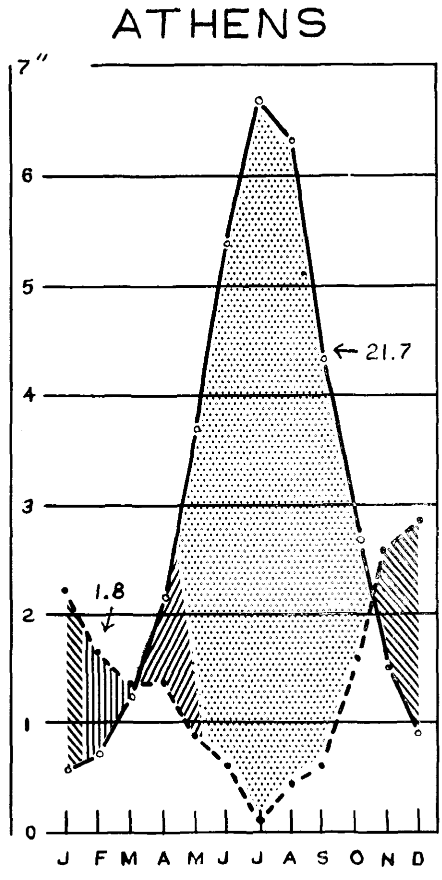


FIGURE 7. Athens, Greece

Danube valley bifurcating northwestward into western Czechoslovakia and southward to the western coast of Greece. Eastern Italy, the major islands of the Mediterranean, southern France, and most of Spain and Portugal are included within the dry climates. Most surprising is the inclusion of the Paris Basin and eastern England within the dry category.

In the United States the zero isarithm is a relatively regular line extending north-south from northwestern Minnesota to coastal Texas. To the east all is humid; to the west with the exception of mountainous areas within the Rockies, Cascades, and Sierra Nevada, only western Washington, western Oregon, and northern California are classified as humid.

The two most extensive climatic types in Europe are the C_2 (moist subhumid) and the C_1 (dry subhumid). C_2, the driest of the humid climates, is most common in northern and northwestern Europe as well as highland areas of southern Europe. In the United States this climatic type is found in a long narrow band from northern Minnesota to the Texas Gulf coast. C_1, the moistest of the dry

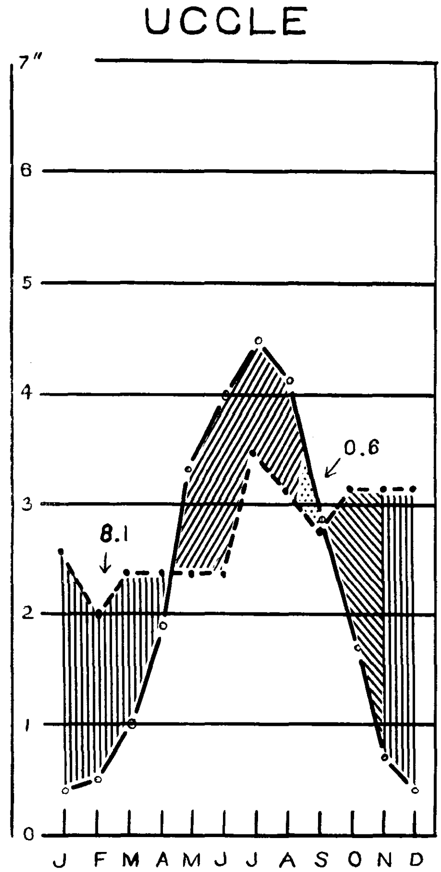


FIGURE 8. Uccle, Belgium

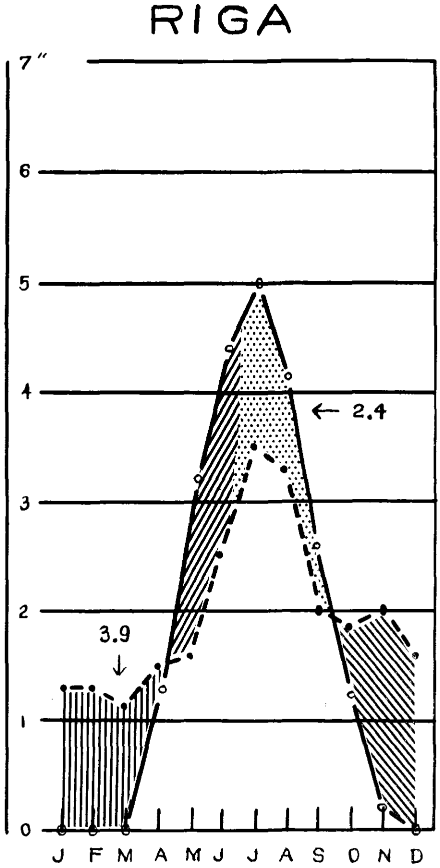
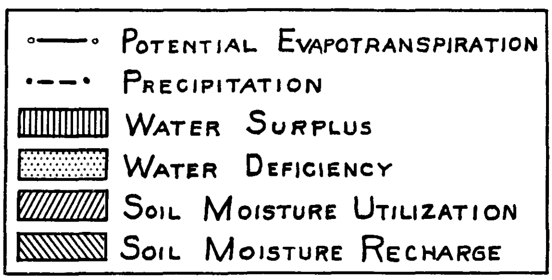


FIGURE 9. Riga, U.S.S.R.



climates includes much of the southern portion of the European section of the Soviet Union, Satellite Europe, and fragments in the Mediterranean borderlands, France, and England. In the United States a narrow band of this climatic extends form northern North Dakota to southern Texas.

Over one-half of Europe thus is classified as moist *subhumid* and dry *subhumid;* only about one-sixth of the United States is so classified.

CLIMATIC STATIONS

Four examples of the four most extensive European climatic types are now presented to point up the regional and temporal contrasts which exist among the climatic regions of that continent.

Magdeburg, East Germany (fig. 6)

Magdeburg, East Germany, exemplifies the most extensive dry climate in Europe, C_1, a *dry subhumid* type, with a moisture index of -20 to 0. Several of Europe's most important agricultural areas such as the Ukraine, the Danube Valley, the Börde, the Paris Basin, and eastern England fall within this climate.

Magdeburg has a relatively large water deficiency of 5.3 in., occurring during the period from mid-May to October, and a small winter water surplus of 1.5 in.

Athens, Greece (fig. 7)

Athens, Greece, characterizes the D or *semiarid* climate, moisture index of -40 to -20. The D climates are found in Spain, Corsica, the southern third of the Balkan peninsula, and in the U. S. S. R. between the Black and Caspian Seas.

An impressively large water deficiency of 21.7 in. during the 5 warmest months is the dominant climatic feature of this station. A winter surplus of 1.8 in. occurs.

Uccle, Belgium (fig. 8)

Uccle, Belgium, represents B_1, a *humid* climate, moisture index 20 to 40. This climate is found on exposed portions of Atlantic coastal Europe, a north-south axis extending from the mouth of the Rhine to the Apennines, and the eastern half of Fenno-Scandia.

Uccle's curve shows a relatively large water surplus of 8.1 in. accumulating during the period November to April, and an almost negligible water deficiency of 0.6 in. occurring late summer.

Riga, U. S. S. R. (fig. 9)

Riga, U. S. S. R., typifies C_2, a *moist subhumid* climate, moisture index 0 to 20. The most extensive climatic type in Europe, the *moist subhumid* climate covers much of France, Germany, northern Poland, and the Soviet Union.

Riga's curve shows a water surplus of 3.9 in., occurring January through March, and a water deficiency of 2.4 in. occurring during the middle and latter parts of the summer.

Table 1

The accompanying table of the 170 stations used in this study is arranged in ascending order of moisture index value. In addition the following data for each station is given: water need, summer need percent, precipitation, water surplus, water deficiency, surplus percent of need, deficiency percent of need, and climatic type. All data was obtained from the Blue Hill Meteorological Observatory. Much of the basic climatic data is now widely available as the result of the publication by the U.S. Weather Bureau of *World Climatic Data 1940-1950*, United States Government Printing Office, October 1959.

TABLE 1

Comparative moisture data

Station	Water need (in./yr)	Summer need (%)	Precipi-tation (in./yr)	Water surplus (in./yr)	Surplus as % of need	Water deficiency (in./yr)	Deficiency as % of need	Moisture index	Climatic type
Astrakhan, U.S.S.R.	29.6	61.9	5.9	0.0	0.0	20.8	70.4	−46.6	$E\ B_1^1\ db_1^1$
Baku, U.S.S.R.	31.0	54.1	9.5	0.0	0.0	21.5	69.4	−40.3	$E\ B_2^1\ db_3^1$
Sulina, Rumania	27.4	56.9	10.7	0.0	0.0	17.4	63.5	−37.5	$D\ B_1^1\ db_3^1$
Alicante, Spain	35.0	46.0	13.2	0.0	0.0	21.8	62.3	−37.4	$D\ B_3^1\ da^1$
Zaragoza, Spain	30.9	50.7	12.3	0.0	0.0	18.6	60.3	−36.0	$D\ B_2^1\ da_4^1$
Cartagena, Spain	36.0	46.7	15.1	0.0	0.0	21.0	58.5	−34.8	$D\ B_3^1\ da^1$
Athens, Greece	36.0	51.0	16.2	2.0	5.5	21.8	60.5	−30.7	$D\ B_3^1\ db_4^1$
Cagliari, Sardinia	34.1	47.0	18.3	0.6	1.8	16.3	47.9	−27.0	$D\ B_3^1\ da^1$
Madrid, Spain	29.4	54.6	16.4	0.4	1.4	13.3	40.2	−25.8	$D\ B_2^1\ db_3^1$
Taranto, Italy	35.4	49.8	20.0	1.9	5.4	17.4	49.1	−23.9	$D\ B_3^1\ db_4^1$
Skoplje, Yugoslavia	30.4	50.2	18.9	0.0	0.0	11.5	37.9	−22.6	$D\ B_2^1\ db_4^1$
Odessa, U.S.S.R.	26.5	59.7	16.1	1.3	4.9	11.3	42.5	−20.5	$D\ B_1^1\ db_2^1$
Saratov, U.S.S.R.	24.7	65.7	14.9	2.2	8.9	12.1	49.0	−20.1	$D\ B_1^1\ db_1^1$
Badagoz, Spain	34.8	49.3	21.2	2.8	8.1	16.3	46.9	−20.0	$D\ B_3^1\ db_4^1$
Seville, Spain	37.7	50.6	22.2	4.5	11.9	20.0	53.0	−19.9	$C_1B_3^1\ sb_4^1$
Salonika, Greece	33.9	53.4	21.6	2.1	6.2	14.5	42.8	−19.3	$C_1B_3^1\ db_3^1$
Barcelona, Spain	32.6	47.0	22.6	0.4	1.2	10.4	31.9	−17.9	$C_1B_2^1\ da^1$
Kazan, U.S.S.R.	21.9	66.8	15.5	0.0	0.0	6.4	29.2	−17.6	$C_1C_2^1\ db_1^1$
Orenburg, U.S.S.R.	23.3	66.8	15.2	2.2	10.6	10.3	44.2	−16.9	$C_1B_1^1\ db_1^1$
Yalta, U.S.S.R.	29.9	55.0	19.2	3.5	12.1	13.8	48.2	−16.1	$C_1B_2^1\ sb_3^1$
Bari, Italy	32.0	49.3	23.0	3.0	9.4	12.4	38.1	−13.8	$C_1B_2^1\ db_4^1$
Praha, Czechoslovakia	24.5	56.1	18.9	0.0	0.0	5.2	21.2	−12.8	$C_1B_1^1\ db_3^1$
Szeged, Hungary	27.9	55.0	21.2	1.4	5.0	8.2	29.4	−12.5	$C_1B_1^1\ db_3^1$
Burgas, Bulgaria	29.0	53.0	21.8	2.4	8.3	9.6	33.1	−11.5	$C_1B_1^1\ db_3^1$
Magdeburg, Germany	24.7	55.0	19.4	1.7	6.9	7.0	28.4	−10.2	$C_1B_1^1\ db_3^1$
Ancona, Italy	33.2	52.0	24.9	4.3	13.0	12.5	37.6	− 9.7	$C_1B_2^1\ sb_3^1$

TABLE 1—*Continued*

Station	Water need (in./yr)	Summer need (%)	Precipitation (in./yr)	Water surplus (in./yr)	Surplus as % of need	Water deficiency (in./yr)	Deficiency as % of need	Moisture index	Climatic type
Sassari, Sardinia	32.5	49.2	23.8	5.4	16.6	14.1	43.5	− 9.4	$C_1B_2^1\ sb_4^1$
Brno, Czechoslovakia	24.9	56.8	20.5	0.9	3.6	5.3	21.4	− 9.0	$C_1B_1^1\ db_2^1$
Poznan, Poland	24.3	57.1	19.9	1.2	5.0	5.6	23.0	− 8.9	$C_1B_1^1\ db_2^1$
Palermo, Italy	34.0	46.7	24.9	6.1	18.0	15.1	44.4	− 8.8	$C_1B_3^1\ sa^1$
Lisbon, Portugal	31.6	42.2	23.8	5.1	16.2	12.9	40.9	− 8.4	$C_1B_2^1\ sa^1$
Mahon, Balearic Is.	33.4	45.9	26.9	3.8	11.4	10.4	31.2	− 7.1	$C_1B_2^1\ sa^1$
Perpignon, France	30.4	49.2	24.8	5.1	16.8	12.0	42.1	− 7.1	$C_1B_2^1\ sb_4^1$
Cambridge, England	25.0	48.7	21.5	1.2	4.8	4.7	18.8	− 6.5	$C_1B_1^1\ db_4^1$
Miskolc, Hungary	26.9	56.0	22.6	1.9	7.1	6.0	22.2	− 6.5	$C_1B_1^1\ db_3^1$
Avignon, France	30.6	52.8	25.0	3.4	11.1	9.0	29.4	− 6.4	$C_1B_2^1\ sb_3^1$
Pecs, Hungary	27.2	55.4	23.0	2.2	8.1	6.5	23.8	− 6.1	$C_1B_1^1\ db_3^1$
Weimar, Germany	23.8	54.8	20.7	1.3	5.5	4.3	18.1	− 5.4	$C_1B_1^1\ db_3^1$
Marseilles, France	29.7	50.6	23.6	5.4	18.2	11.5	38.8	− 5.1	$C_1B_2^1\ sb_4^1$
Bucharest, Rumania	27.1	56.3	23.1	2.6	9.6	6.6	24.4	− 4.9	$C_1B_1^1\ db_2^1$
Split, Yugoslavia	36.2	52.8	27.7	8.2	22.6	16.6	45.9	− 4.8	$C_1B_3^1\ s_2b_3^1$
Chateaudun, France	26.0	51.8	22.4	2.5	9.6	6.1	23.4	− 4.3	$C_1B_1^1\ db_4^1$
Auxerre, France	26.4	51.4	23.4	2.0	7.6	5.1	19.6	− 3.9	$C_1B_1^1\ db_4^1$
Belgrade, Yugoslavia	27.7	54.2	24.3	2.4	8.7	5.8	21.0	− 3.7	$C_1B_1^1\ db_3^1$
Debrecen, Hungary	26.7	55.9	23.4	2.7	10.1	6.1	22.8	− 3.5	$C_1B_1\ sb_3^1$
Kiev, U.S.S.R.	23.9	60.5	21.0	2.8	11.7	5.8	24.2	− 2.8	$C_1B_1\ sb_2^1$
Paris, France	26.3	49.4	24.0	2.3	8.7	5.0	19.0	− 2.4	$C_1B_1^1\ db_4^1$
Patrai, Greece	37.2	50.1	28.5	11.1	29.8	19.9	53.5	− 2.1	$C_1B_3^1\ s_2b_4^1$
Lindenberg, Germany	24.4	55.4	22.0	2.4	9.8	4.8	19.7	− 2.1	$C_1B_1^1\ db_3^1$
Nottingham, England	24.5	48.1	22.5	2.0	8.2	4.0	16.4	− 1.7	$C_1B_1^1\ da^1$
Catania, Italy	37.2	50.4	28.2	12.7	34.1	22.0	59.0	− 1.4	$C_1B_3^1\ s_2b_4^1$
Warsaw, Poland	24.2	55.0	22.0	2.4	10.0	4.4	18.2	− 1.2	$C_1B_1^1\ db_3^1$

Stettin, Poland	24.3	56.5	21.9	2.8	11.5	5.1	21.0	− 1.2	$C_1B_1^1$	sb_2^1
Magyarovar, Hungary	26.5	53.3	23.6	3.2	12.1	5.7	21.5	− 0.9	$C_1B_1^1$	sb_3^1
Frankfurt, Germany	26.3	52.4	24.1	2.8	10.7	5.0	19.0	− 0.5	$C_1B_1^1$	sb_3^1
Clermont-Ferrand, France	26.1	50.6	25.2	1.1	4.2	1.9	7.6	− 0.2	$C_1B_1^1$	db_4^1
Sibiu, Rumania	25.4	56.1	24.1	2.0	7.9	3.4	13.4	− 0.1	$C_1B_1^1$	db_3^1
Budapest, Hungary	28.4	55.4	24.8	4.1	14.4	6.9	24.3	− 0.1	$C_1B_2^1$	sb_3^1
Wroclaw, Poland	24.6	57.0	22.9	2.0	8.2	3.1	12.6	+ 0.4	$C_2B_1^1$	rb_2^1
Leningrad, U.S.S.R.	20.6	65.6	19.2	2.5	12.0	3.9	18.7	+ 0.8	$C_2C_2^1$	sb_1^1
Kassel, Germany	24.3	52.5	23.4	2.6	10.7	3.5	14.4	+ 1.7	$C_2B_1^1$	rb_3^1
Sofia, Bulgaria	25.8	55.1	24.9	2.4	9.3	3.3	12.8	+ 1.7	$C_2B_1^1$	rb_3^1
London, England	25.7	48.5	25.1	2.6	10.1	3.5	13.6	+ 2.0	$C_2B_1^1$	ra^1
York, England	25.0	47.7	24.3	2.5	10.0	3.2	12.8	+ 2.3	$C_2B_1^1$	ra^1
Visby, Sweden	21.8	57.5	20.4	3.7	17.0	5.1	23.4	+ 2.7	$C_2C_2^1$	sb_2^1
Berlin, Germany	24.5	55.5	23.5	3.6	14.7	4.6	18.8	+ 3.1	$C_2B_1^1$	sb_3^1
Brest, France	22.5	63.3	21.7	3.2	14.2	4.1	18.2	+ 3.3	$C_2B_1^1$	sb_1^1
Nurnberg, Germany	23.9	55.4	23.7	2.8	11.7	3.1	13.0	+ 3.9	$C_2B_1^1$	rb_3^1
Venice, Italy	30.6	54.0	29.3	5.3	17.3	6.7	21.9	+ 4.1	$C_2B_2^1$	sb_3^1
Stuttgart, Germany	25.7	52.5	26.1	2.1	8.2	1.8	7.0	+ 4.1	$C_2B_1^1$	rb_3^1
Bourges, France	26.5	48.8	26.1	3.7	14.0	4.1	15.5	+ 4.5	$C_2B_1^1$	rb_4^1
Archangel, U.S.S.R.	17.1	73.3	16.9	2.5	14.6	2.8	16.4	+ 4.8	$C_2C_2^1$	rc_2^1
Toulouse, France	28.5	50.2	27.4	4.3	14.0	4.3	15.1	+ 5.1	$C_2B_2^1$	rb_4^1
Hawarden, England	26.5	44.3	27.0	2.8	10.6	2.3	8.7	+ 5.3	$C_2B_1^1$	ra_1^1
Oxford, England	25.1	48.5	25.5	3.3	13.2	3.0	12.0	+ 5.8	$C_2B_1^1$	rb_4^1
Leipzig, Germany	24.8	55.0	25.0	3.3	13.3	3.1	12.5	+ 5.9	$C_2B_1^1$	rb_2^1
Groningen, Netherlands	24.2	52.8	26.6	2.5	10.3	1.7	7.0	+ 6.1	$C_2B_1^1$	rb_3^1
Moscow, U.S.S.R.	21.8	65.5	21.5	3.7	16.9	3.9	17.9	+ 6.3	$C_2C_2^1$	sb_1^1
Dresden, Germany	24.3	54.3	25.4	2.8	11.5	2.0	8.2	+ 6.4	$C_2B_1^1$	rb_3^3
Great Yarmouth, England	24.5	48.3	24.5	3.7	15.1	3.4	13.9	+ 6.7	$C_2B_1^1$	rb_4^1
Kobenhavn, Denmark	23.7	55.9	23.9	3.6	15.2	3.3	13.9	+ 6.7	$C_2B_1^1$	rb_3^1
Skagen, Denmark	22.8	55.0	23.0	3.7	16.3	3.5	15.4	+ 7.0	$C_2B_1^1$	rb_3^1
Ste. Honorine, France	25.7	48.1	27.4	4.4	17.1	3.8	14.8	+ 8.4	$C_2B_1^1$	rb_4^1

TABLE 1—*Continued*

Station	Water need (in./yr)	Summer need (%)	Precipitation (in./yr)	Water surplus (in./yr)	Surplus as % of need	Water deficiency (in./yr)	Deficiency as % of need	Moisture index	Climatic type
Bologna, Italy	32.2	52.0	29.8	8.2	25.5	9.0	28.0	+ 8.7	$C_2B_2^1$ sb_3^1
Istanbul, Turkey	29.7	50.7	28.8	9.1	30.6	10.6	35.6	+ 9.2	$C_2B_2^1$ $s_2b_4^1$
Rouen, France	25.8	50.3	27.5	4.6	17.9	3.5	13.6	+ 9.6	$C_2B_1^1$ rb_4^1
Köln, Germany	26.3	50.2	27.4	4.6	17.5	3.4	12.9	+ 9.9	$C_2B_1^1$ rb_4^1
Wien, Austria	25.3	54.8	26.9	4.1	16.2	2.5	9.9	+10.2	$C_2B_1^1$ rb_3^1
Ostersund, Sweden	17.9	67.5	19.8	2.9	16.2	1.1	6.1	+10.2	$C_2C_2^1$ rb_1^1
Lille, France	25.3	50.5	27.0	4.9	19.4	3.5	13.8	+10.9	$C_2B_1^1$ rb_4^1
Dublin, Ireland	25.4	45.7	27.4	3.8	14.6	1.7	6.7	+11.0	$C_2B_1^1$ ra^1
Strasbourg, France	25.3	52.1	27.6	3.4	13.5	1.0	4.0	+11.0	$C_2B_1^1$ rb_3^1
Uppsala, Sweden	20.3	63.5	21.4	4.2	20.7	3.0	14.8	+11.5	$C_2C_2^1$ rb_1^1
Lyon, France	26.5	51.2	29.3	4.2	15.9	1.6	6.1	+12.1	$C_1B_2^1$ rb_4^1
Nice, France	31.2	48.6	30.8	9.9	31.7	10.2	32.4	+12.3	$C_1B_2^1$ sb_4^1
Jonkoping, Sweden	20.8	60.7	22.8	4.1	19.7	2.6	12.5	+12.3	$C_2C_2^1$ rb_2^1
Livorno, Italy	32.2	31.7	32.3	10.1	32.4	10.2	32.7	+12.3	$C_2B_2^1$ sb^1
Messina, Italy	34.9	48.7	33.3	13.3	38.1	14.9	42.7	+12.4	$C_2B_3^1$ $s_2b_4^1$
Warnemünde, Germany	23.3	54.3	24.3	4.2	18.0	2.1	9.0	+12.5	$C_2B_1^1$ rb_3^1
Riga, U.S.S.R.	21.2	63.5	23.6	4.1	19.4	2.4	11.3	+12.5	$C_2C_2^1$ rb_1^1
Edinburgh, Scotland	23.9	47.6	27.2	3.4	14.2	0.3	1.3	+13.5	$C_2B_1^1$ ra^1
Stockholm, Sweden	21.0	60.6	22.9	4.6	21.9	2.7	12.9	+13.7	$C_2C_2^1$ rb_2^1
St. Polten, Austria	23.9	55.6	28.0	3.4	14.2	0.0	0.0	+14.1	$C_2B_1^1$ rb_3^1
Brest, France	25.9	42.5	28.1	6.0	23.2	3.9	15.1	+14.3	$C_2B_1^1$ ra^1
Emden, Germany	24.1	52.8	28.8	4.4	18.3	1.2	5.0	+15.1	$C_2B_1^1$ rb_3^1
Montpellier, France	29.4	51.9	30.9	9.0	30.6	7.3	24.8	+15.7	$C_2B_2^1$ sb_3^1
Tvingstrup, Denmark	22.1	55.9	24.7	5.1	23.1	2.4	10.9	+16.5	$C_1C_2^1$ rb_3^1
Naples, Italy	32.3	48.1	33.5	12.2	37.5	11.0	34.2	+17.4	$C_2B_2^1$ $s_2b_4^1$
Fanö, Denmark	23.0	57.2	25.9	5.7	24.8	2.6	11.3	+18.0	$C_2B_1^1$ rb_2^1
Neustrelitz, Germany	23.7	56.5	26.8	6.0	25.4	2.8	11.8	+18.2	$C_2B_1^1$ rb_2^1
Karesuando, Sweden	15.0	77.1	12.7	4.4	29.3	2.7	18.0	+18.5	$C_2C_1^1$ sc_1^1

Gorlitz, Germany	24.1	55.6	28.1	5.3	22.0	1.2	5.0	+19.0	$C_2B_1^1$ rb_3^1
La Coruna, Spain	27.7	40.1	31.9	8.6	31.1	5.2	18.6	+19.7	$C_2B_1^1$ sa^1
Rome, Italy	33.1	51.0	35.1	1.4	4.2	1.2	3.6	+20.3	$B_1B_2^1$ $s_2b_4^1$
Karlstad, Sweden	21.4	61.1	24.7	5.8	27.1	2.3	10.8	+20.5	$B_1C_2^1$ rb_2^1
Vaasa, Finland	18.6	66.5	21.5	5.2	27.9	2.3	12.4	+20.5	$B_1C_2^1$ rb_1^1
Bordeaux, France	27.6	47.4	31.9	8.6	31.2	4.4	16.0	+21.2	$B_1B_1^1$ ra^1
Kaliningrad, U.S.S.R.	22.7	58.6	27.0	6.0	26.4	1.7	7.5	+22.0	$B_1B_1^1$ rb_2^1
Gilbraltar	33.7	42.1	35.7	15.9	47.2	13.8	41.0	+22.7	$B_1B_3^1$ s_2a^1
Debilt, Netherlands	24.5	49.5	29.8	6.4	26.1	1.2	4.9	+23.2	$B_1B_1^1$ rb_4^1
Vestervig, Denmark	22.6	52.1	27.9	6.8	30.1	2.5	11.1	+23.4	$B_1B_1^1$ rb_3^1
Goteborg, Sweden	23.2	55.7	28.0	6.4	27.6	1.6	6.9	+23.4	$B_1B_1^1$ rb_3^1
Trier, Germany	25.3	51.4	30.8	6.6	26.1	1.1	4.4	+23.5	$B_1B_1^1$ rb_4^1
Cremona, Italy	30.2	55.6	34.8	11.5	38.1	6.9	22.9	+24.2	$B_1B_2^1$ sb_3^1
Turku, Finland	20.6	63.7	23.7	6.6	32.0	2.8	13.6	+24.4	$B_1C_2^1$ rb_1^1
Hamburg, Germany	23.9	54.2	29.4	6.6	27.6	1.2	5.0	+24.6	$B_1B_1^1$ rb_3^1
Basel, Switzerland	25.5	52.4	32.2	6.7	26.3	0.0	0.0	+26.2	$B_1B_1^1$ rb_3^1
Nantes, France	26.2	48.1	32.1	9.9	37.8	4.1	15.7	+26.7	$B_1B_1^1$ rb_4^1
Milano, Italy	30.0	55.3	36.6	12.2	40.6	5.7	19.0	+29.4	$B_1B_2^1$ sb_3^1
Zagreb, Yugoslavia	27.3	53.9	34.9	8.7	31.8	1.1	4.0	+29.4	$B_1B_1^1$ rb_3^1
Haparanda, Sweden	17.0	70.8	20.9	7.0	41.2	3.1	18.2	+30.1	$B_1C_2^1$ sc_2^1
Uccle, Belgium	25.3	49.6	32.9	8.3	32.8	0.6	2.4	+31.1	$B_1B_1^1$ rb_4^1
Sodankyla, Finland	15.7	76.1	20.4	5.4	34.4	0.6	3.8	+31.7	$B_1C_1^1$ rc_2^1
Malin Head, Ireland	24.2	43.9	32.0	7.7	31.8	0.0	0.0	+31.8	$B_1B_1^1$ ra^1
Kajaani, Finland	17.4	70.6	22.8	6.0	34.5	0.6	3.5	+32.2	$B_1C_2^1$ rc_2^1
Cill Cainnig, Ireland	24.7	46.2	33.2	8.5	34.4	0.0	0.0	+34.2	$B_1B_1^1$ ra^1
Lvonetjarvi, Finland	19.2	66.1	25.1	7.1	36.9	0.8	3.1	+34.5	$B_1C_2^1$ rb_1^1
Chaumont, France	25.1	52.9	33.7	9.6	38.2	1.0	4.0	+34.9	$B_1B_1^1$ rb_3^1
Helsinki, Finland	20.3	63.0	26.7	9.3	45.8	3.2	15.5	+36.0	$B_1C_2^1$ rb_1^1
Geneve, Switzerland	26.6	50.4	36.4	9.9	37.2	0.0	0.0	+36.9	$B_1B_1^1$ rb_4^1
Luxembourg, Luxembourg	24.1	53.5	32.3	9.4	39.0	1.2	5.0	+38.9	$B_1B_1^1$ rb_4^1
München, Germany	23.4	53.9	34.9	9.3	39.7	0.0	0.0	+39.6	$B_1B_1^1$ rb_3^1
Aberdeen, Scotland	22.8	47.2	31.9	9.1	40.0	0.0	0.0	+40.1	B_2B_1 ra^1

TABLE 1—*Continued*

Station	Water need (in./yr)	Summer need (%)	Precipitation (in./yr)	Water surplus (in./yr)	Surplus as % of need	Water deficiency (in./yr)	Deficiency as % of need	Moisture index	Climatic type
Trieste	31.8	51.3	43.7	13.6	42.6	1.1	3.5	+40.4	$B_2B_2^1$ rb_4^1
St. Anns Head, Wales	25.4	43.8	35.2	10.5	41.4	0.3	1.2	+41.4	B_2B_1 ra^1
Aldergrove, N. Ireland	24.3	45.2	34.4	10.2	42.0	0.0	0.0	+42.0	$B_2B_1^1$ ra^1
Innsbruck, Austria	23.9	54.4	34.4	10.5	44.0	0.0	0.0	+44.0	$B_2B_1^1$ rb_3^1
Olso, Norway	21.4	62.5	30.2	10.1	48.2	0.8	3.7	+44.5	$B_2C_2^1$ rb_1^1
Graz, Austria	24.6	53.4	36.3	11.6	47.2	0.0	0.0	+47.3	$B_2B_1^1$ rb_3^1
Mount Batten, England	25.6	43.1	38.3	12.8	50.0	0.4	1.6	+49.6	$B_2B_1^1$ ra^1
Corfu, Greece	36.5	48.7	48.9	27.4	75.0	15.1	41.4	+50.4	$B_2B_3^1$ $s_2b_4^1$
Trondheim, Norway	18.8	62.2	28.1	10.2	56.6	0.9	5.0	+51.4	$B_2C_2^1$ rb_1^1
Glasgow, Scotland	24.1	46.5	94.4	13.2	54.7	0.0	0.0	+54.7	$B_2B_1^1$ ra^1
Friedrichshafen, Germany	24.1	53.7	37.3	13.2	54.7	0.0	0.0	+54.9	$B_2B_1^1$ rb_3^1
Bilbao, Spain	30.2	44.1	47.8	19.0	63.0	1.5	5.0	+59.8	$B_2B_2^1$ ra^1
Krynica, Poland	21.8	57.9	36.2	14.5	66.5	0.0	0.0	+66.4	$B_3C_2^1$ rb_2^1
Genoa, Italy	32.3	39.5	51.7	24.6	76.2	5.3	16.4	+66.5	$B_3B_2^1$ ra^1
Klagenfurt, Austria	24.2	55.9	40.1	16.4	67.9	0.0	0.0	+67.6	$B_3B_1^1$ rb_3^1
Zurich, Switzerland	24.1	53.9	41.3	17.3	71.7	0.0	0.0	+71.4	$B_3B_1^1$ rb_3^1
Lerwick, Shetland Is.	22.4	44.2	38.7	16.0	71.5	0.0	0.0	+71.5	$B_3C_2^1$ ra^1
Markee Castle, Ireland	24.1	45.6	45.5	18.7	77.6	0.0	0.0	+77.5	$B_3B_1^1$ ra^1
Vardö, Norway	14.5	69.1	25.7	12.0	82.9	0.8	5.5	+79.4	$B_3C_1^1$ rc_2^1
Luzern, Switzerland	23.9	54.7	44.2	19.7	82.5	0.0	0.0	+82.5	$B_4B_1^1$ rb_3^1
Reykjavik, Iceland	19.0	57.1	35.7	17.7	93.1	1.3	6.9	+88.6	$B_4C_2^1$ rb_2^1
Salzburg, Austria	24.1	54.3	54.4	27.2	113.0	0.0	0.0	+113.0	AB_1^1 rb_3^1
Bodö, Norway	18.4	61.3	40.2	21.8	118.2	0.0	0.0	+119.0	AC_2 rb_2^1
Valentia, Ireland	25.1	42.3	57.5	32.5	129.5	0.0	0.0	+129.1	AB_1^1 ra^1
Tromso, Norway	15.8	69.8	37.0	21.4	135.5	0.2	1.3	+135.0	AC_1^1 rc_2^1
Lugano, Switzerland	27.9	52.2	65.7	39.0	139.5	0.0	0.0	+139.5	AB_1^1 rb_3^1
Batumi, U.S.S.R.	30.2	50.1	93.2	63.4	209.2	0.0	0.0	+209.2	AB_2^1 rb_4^1
Bergen, Norway	22.9	50.4	76.7	50.6	220.0	0.0	0.0	+220.0	AB_1^1 rb_4^1

LITERATURE CITED

Burgos, J., and **A. Vidal.** 1951. The climates of the Argentine Republic according to the new Thornthwaite classification. Ann. Assoc. Am. Georg. 41: 237–263.

Chang, J. 1955. The climate of China according to the new Thornthwaite classification. Ann. Assoc. Am. Geogr. 45: 393–403.

———. 1959. An evaluation of the 1948 Thornthwaite classification. Ann. Assoc. Am. Geogr. 49: 24–30.

Erinc, S. 1950. Climatic types and the variation of moisture regions in Turkey. Geogr. Rev. 40: 224–235.

Garnier, B. 1951. Thornthwaite's new system of climatic classification in its application to new Zealand. Trans. Royal Soc. of New Zealand. 87–103.

Howe, G. 1953. Climates of the Rhodesias and Nyasaland according to the Thornthwaite classification. Geogr. Rev. 43: 525–539.

Sanderson, M. 1948. The climates of Canada according to the new Thornthwaite classification. Sci. Am. 28: 501–517.

Thornthwaite, C. 1948. An approach toward a rational classification of climate. Geogr. Rev. 38: 55–94.